CHAPTER 4

Cable Wiring

Cable systems are used where cost is a factor. They can be installed easily, and the material required is less expensive than that used for other systems. The absence of protection against mechanical injury and the fact that it is only moisture-resistant tend to restrict the areas where the cable system can be used. Temporary and expedient-wiring cable systems are ideally suited for the TO.

Section I. Armored Cable Wiring

ADVANTAGES AND USES

Armored-cable wiring is permissible by regulation for all interior installations, except where it is exposed to saturation by liquid or where it is in contact with acid fumes. In wet areas, a lead-covered cable is required. Because the material requirements for armored-cable wiring are greater, the overall cost is generally higher than Type NM cable systems. This increased cost is often warranted because an armored conductor has greater mechanical-damage protection. The installation of armored cable is relatively simple and is similar to that of nonmetallic-sheathed cable discussed in Section II. Much of the equipment and materials are the same.

MATERIALS

CABLE

Armored-cable construction consists of two or three rubber- or thermoplastic-covered wire combinations encased in flexible steel armor. Cable is obtained from the manufacturer as Type AC (without a lead sheath) and Type ACL (with a lead sheath under the armor). Type AC cable has a copper or aluminum bonding strip.

One of the conductors of armored cable is always white. Because of this color coding, the white wire in a switch installation (for both armored cable and nonmetallic-sheathed cable) can be used as a hot wire and be connected to a black wire.

SUPPORT

Armored cable may be fastened to wooden building members with a one- or two-hole mounting strap formed to fit the contour and size of the cable or by staples made specifically for armored cable. The cable is normally supported at the box entry either by integral armored-cable clamps built into the boxes or by armored-cable connectors.

BOXES AND DEVICES

Chapter 2 details boxes and devices recommended for use with armored-cable wiring. Electrical boxes with integral cable clamps and attached mounting brackets are used for quick installation.

INSTALLATION

CABLE SUPPORT

Whenever possible, run armored cable through holes centrally drilled in the building structural members and ensure that the holes are at least 1/8 inch oversize to facilitate easy *pull-through* of the armored cable. Avoid the flush-type mounting of armored cable accomplished by notching the joists and studs if possible because this type of installation exposes the armored cable to possible short circuits (by locating the cable in a position where it could be accidentally pierced by nails) and materially weakens the structural member.

When running armored cable between joists and studs, ensure that it is supported by staples or straps at least every 4 1/2 feet along the length of the cable run. These supports must also be installed within 12 inches of each box entry, unless the support interferes with installations that require extreme flexibility. This requirement assures the continuance of a satisfactory box connection by relieving the strain on the splices and the connection within the outlet box. When installing cable runs across the bottom of ceiling joists and stud faces at least 7 feet above the floor, ensure that runs are supported on each joist or stud. You may also install cable runs on running boards similar to those used in open-wiring installations.

Damage Protection

When installing armored cable on the top of ceiling joists or studs in accessible locations (such as attics and temporary buildings) at a distance of less than 7 feet from the floor, you must install guard strips at least as high as the cable.

Bending

When installing armored cable, avoid bending or shaping the cable in a manner that damages the protective armor. This type of installation damage may occur in drilled holes for armored cable, in corner runs, or when locating boxes on studs and joists. To prevent this, follow the rule that the radius of the inner edge of any bend must not be less than five times the cable diameter. *Figure 4-1* illustrates an acceptable armored-cable bend at the box entry.

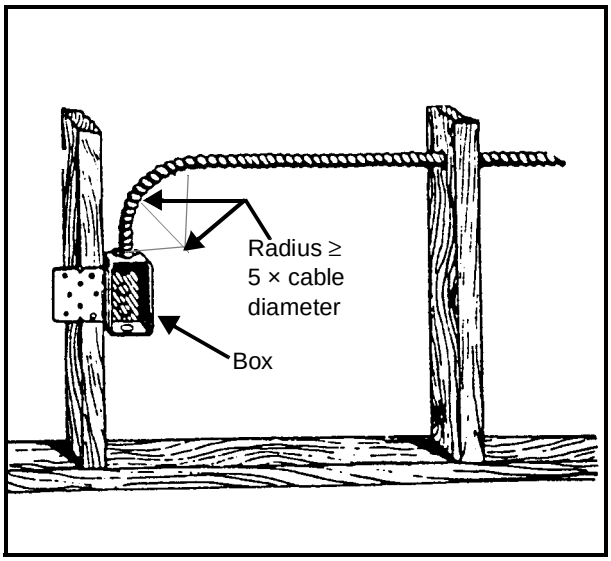


Figure 4-1. Armored-cable bend

BOX CONNECTION

Procedure

Armored cable may be spliced or connected to devices only in standard junction or outlet boxes. Therefore, you must cut all cable long enough to run from box to box. To prevent cutting the cable too short, first thread the armored cable through the mounting holes drilled in the joists or studs and attach the cable to one box. Take the slack out of the cable by using just enough force to maintain the proper bends. Keeping this tension, cut the cable from the roll and connect it to the box. *Figure 4-2* shows the procedure for preparing and attaching the cable to a box.

Cutting Cable

Though armored cable can be cut with an armored-cable cutter specifically designed for the job, most electricians use a hacksaw. When making an outlet connection, cut the cable about 8 inches longer on each end than is required for the run. When removing the armor from the wire, cut the armor approximately 8 inches from the cable end so that ample wire will be inserted in the box for

connecting to the outlet device. These lead lengths may be increased when the wire run terminates in a fuse box or a circuit-breaker panel and a longer cable is required.

Cutting cable armor is a simple operation. With the hacksaw in one hand and the cable end held firmly in the other hand, make the cut with the blade of the hacksaw placed at a right angle to the lay of the armor strip. The hacksaw and the cable should form two legs of a 60-degree triangle. When the blade has cut almost through the armor strip, bend the cable end back and forth several times until it breaks. You can then strip the loose armor from the wire leads by twisting and pulling. If one end of the cable has already been attached to a box, pull the cable tight enough to assure a steady sawing surface. When cutting from a coil, hold the armor firmly by stepping on the coil cable end and pulling it tight. Smooth rough or sharp ends of the cut with a file.

WARNING

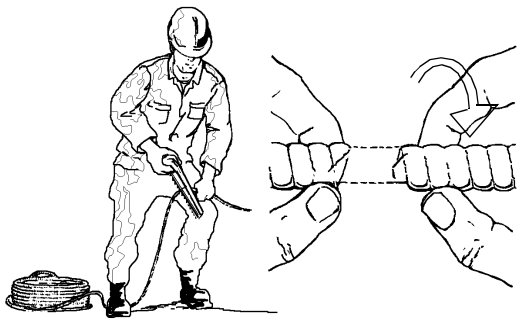
Avoid damaging the wire insulation or the metal bonding strip when cutting cable armor.

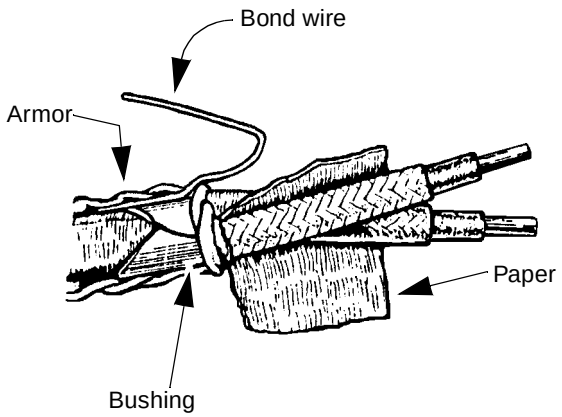
Unwrapping Paper

The fiber paper that is twisted around the conductors before the metallic armor is attached must be removed to allow free wire movement. Normally, you can remove two or three turns of the paper from under the armor by using a jerking action to tear the loose paper away from the wire at the armor end. The free space between the armor and the wires facilitates mounting the antishort bushing.

Attaching Antishort Bushing

When the ends of the cut armor are filed, only the outer burred edges are removed. The inner edges are always sharp and jagged at the cut end, and if not covered, they tend to puncture the wire insulation and cause short circuits and grounds. To prevent this and to protect the wire against





Left: Cutting the armor which is held taut by stepping on it and holding it over the knee.

Right: Note that the armor is cut at an angle to the lay.

Figure 4-2. Cutting and attaching cable

damage, you must insert a tough fiber bushing, commonly called an *antishort bushing*, between the armor and the wire.

Attaching Cable to a Box

When using an armored-cable connector, first insert the cable in the connector and then tighten the holding screw, securely connecting the cable and connectors. Then, insert the armored-cable connector through the box knockout opening, and secure it to the box with the locknut threaded on the connectors from inside the box.

When using the cable with a box having internal cable clamps, first remove the knockout at the point of entry. Next, loosen the clamp-holder screw, insert the cable through the knockout opening, and thread the leads through the clamp (*Figure 4-3*). Then, force the armor snugly against the clamp end and retighten the clamp screw, forcing the clamp into the ridges of the cables.

The bonding wire runs the entire length of the cable and must be bonded to the enclosure on the other receptacle into which the cable is entered. Bend the wire back over the cable before installing the connector or attaching it to a box with an internal clamp.

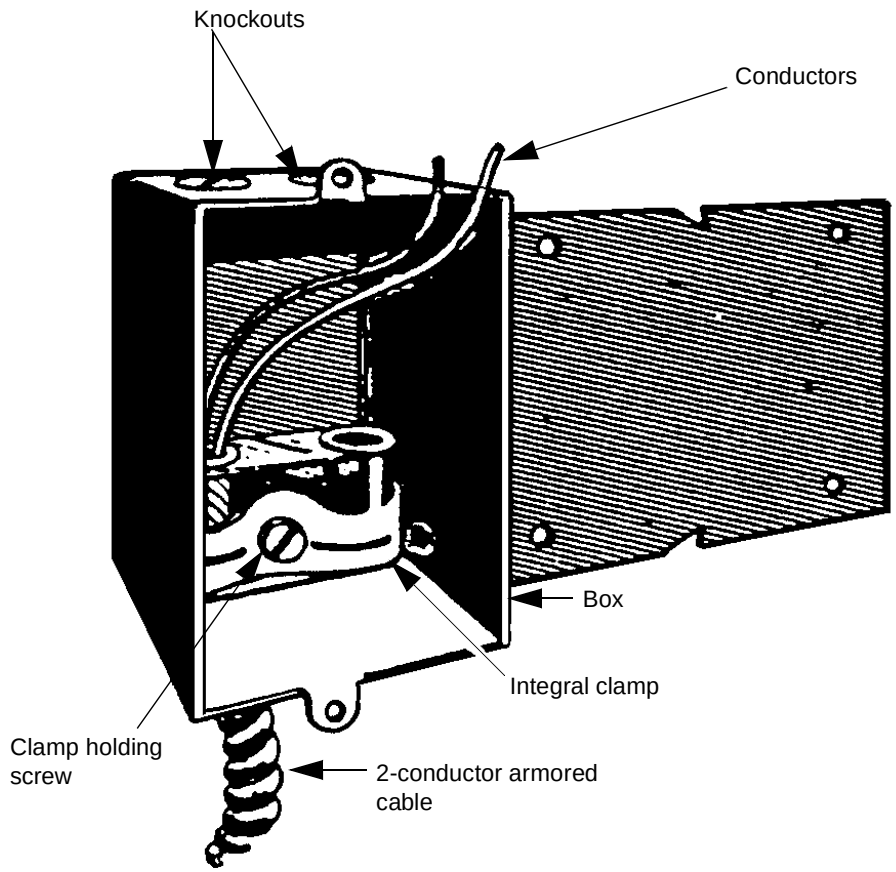


Figure 4-3. Cable connection to box with internal clamps

ADDITIONS TO EXISTING WIRING

CIRCUITING

Additions to existing armored-cable layouts require analysis to determine whether additional circuit capacity will be needed to handle the new load. These considerations are the same as those required for other types of installations.

CABLE CONNECTIONS

Armored-cable additions must always originate and terminate in electrical boxes. The junction box used for the addition should be located close enough to the desired outlets so that the voltage drop to the new device is within allowable limits. The box from which the additional outlet or outlets are to originate must have a neutral and a hot wire of the same circuit for the new load connection. This means that the conductors from an added outlet can be connected only to the conductors of an existing cable in an outlet box (white to white and black to black) if the existing conductors can be traced to the fuse or circuit breaker without interruption.

ARMORED-CABLE ADDITIONS

Exposed

The installation of exposed armored-cable additions to existing wiring must be patterned according to rules outlined for original installations. If an armored-cable installation is to be made into another type of wiring system, the changeover must be made in a junction box specifically installed for the purpose or in an existing outlet box if its conductor capacity will allow the entry of additional wires.

Concealed

Armored cable is preferred over all other types of wiring when additional outlets are required on completed buildings. The armor and the bonding strip provide adequate, continuous ground-to-metal outlet boxes. Armored cable is also flexible enough to be fed through small openings from attic or basement areas to boxes mounted on walls and ceilings. To do this, you will usually pull the cable into the concealed box with a fish tape or a drop chain. Use a fish tape when the cable will be fed from below the box location, and use a drop chain when the installation is to be made from above the box. In these cases, place the junction box in which the power tap is to be made in a clear, readily accessible area because the fishing and catching of a fish tape and a drop chain become a tedious and time-consuming operation if the junction box is concealed (see Section III). If it is difficult to feed into the power-tap box because of building construction, the finished wall may have to be removed to allow entry. If so, replastering will be necessary after the additional cable has been installed.

Section II. Nonmetallic-Sheathed Cable Wiring

ADVANTAGES AND USES

The conventional nonmetallic-sheathed cable, Type NM, is approved for use in concealed or exposed, dry, indoor locations and is recommended for use where a good system ground is not available. Since the cable is inexpensive and lightweight and requires no special installation tools, it is suited for use in military wiring systems. Because of its construction, nonmetallic-sheathed cable is **not** approved for imbedded installation in masonry, concrete, fill, or plaster.

WARNING

Do not install Type NM cable in potentially dangerous areas where wire damage may occur, such as commercial garages, theaters, storage-battery rooms, or hoistways. Additionally, do not use it in humid or wet areas, such as ice plants or cold-storage warehouses.

A newer nonmetallic-sheathed cable, Type NMC, is a dual-purpose, plastic-sheathed cable with solid-copper conductors. This cable needs no conduit, and its flat shape and gray or ivory color make it ideal for surface wiring. It resists moisture, acid, and corrosion and can be run through masonry and between studding.

MATERIALS

CABLE

Type NM cable consists of rubber- or thermoplastic-covered wires in two- or three-wire combinations, with a bare copper wire used for bonding. These wires are individually wrapped with a spiral paper tape for damage protection. The local codes in some areas also require the addition of a bare, uninsulated conductor in Type NMC cable. This bare wire provides the same type of equipment ground or bonding at the outlet boxes as the armor in armored-cable installation. The bare wire is attached to the outlet box by using a grounding clip *(Figure 4-4*).

SUPPORT

Types NM and NMC cable are generally mounted on wooden building members with one- or two-hole mounting straps or staples. Armored-cable staples are **not** approved for this type of installation because of possible cable damage.

BOXES AND DEVICES

The boxes and devices used in Type NM and NMC cable wiring are similar to those used with conduit. They are made of metal or nonmetallic materials and come with built-in clamps or knockout holes for the connectors. Use metal boxes with internal clamps when possible to assure a safe, efficient installation. In exposed Type NM cable wiring, you may use insulated switches, outlets, and lamp-holder devices without boxes. The cable entry holes of these devices must clamp the cable securely, and the device must fully enclose the section of the cable from which the outer sheathing has been removed. Because no splicing is possible in these devices and all wires must be

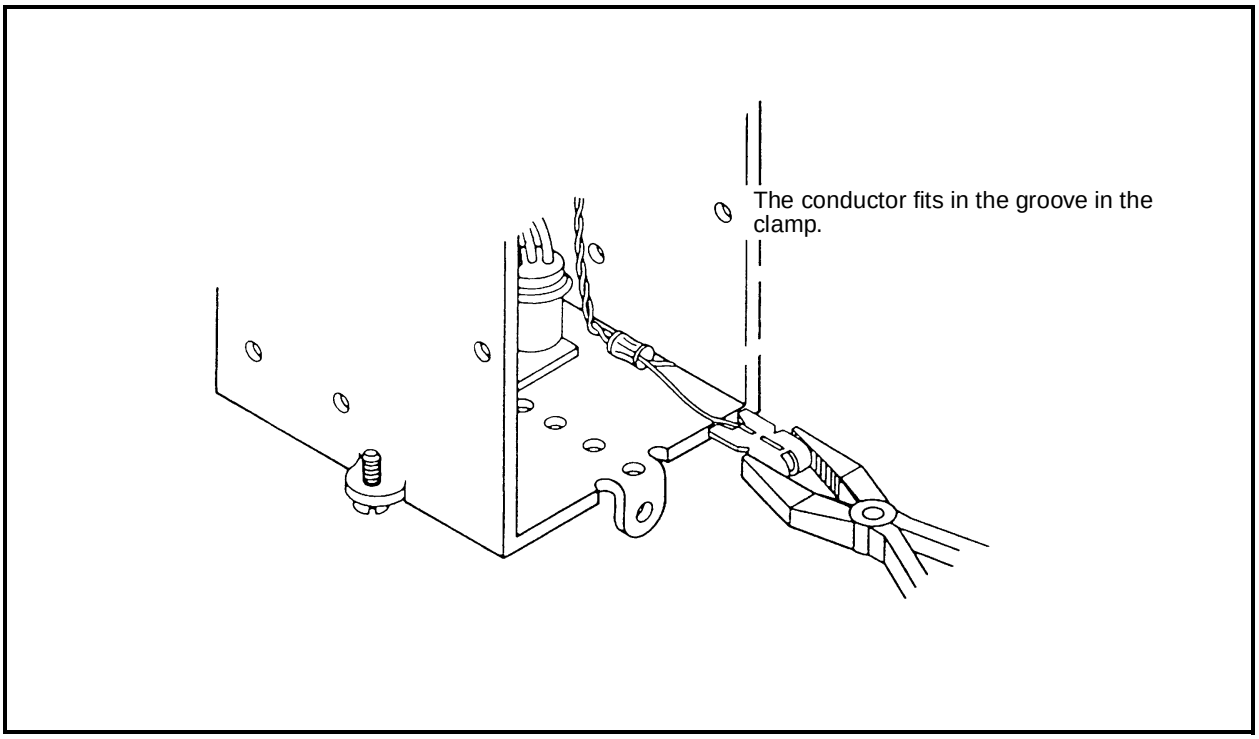


Figure 4-4. Installing a grounding clip

connected to terminals, limit the use of these devices to installation in rural areas or other areas in which only a small number of outlets and switches are required.

INSTALLATION

CABLE SUPPORT

Nonmetallic-sheathed cable should be supported in a manner similar to that outlined for armored cable (Section I). You can install cable on running boards, in holes drilled in the center of the joists, or on the sides of joists and studs. When using running boards or the sides of joists and studs, ensure that straps support the cable at distances not greater than 4 1/2 feet, and attach a cable strap within 12 inches of a box. When you are making the cable run at an angle in an overhead installation and supporting it on the edge of the joists, you must install the cable on running boards. Assemblies containing two No 6 or three No 8 conductors may be secured directly on the bottom of the joist.

DAMAGE PROTECTION

If you install the cable across the top of a floor or floor joist, protect it with guard strips that are at least as high as the cable. When the wire installation is in a location not normally used, such as an attic or a crawl space, damage-protection devices such as guard strips are required only within 6 feet of the entrance. If possible, do not install concealed cable near baseboards, door and window casings, or other possible locations of trim or equipment because of damage from building nails. If you are installing thermal insulation where cable is in place, use only noncorrosive, noncombustible, nonconductive insulation. While installing the insulation, avoid adding additional strain on the cable, its supports, or its terminal connections.

CABLE BENDING

To prevent accidental damage to the sheathing on Type NMC cable, the minimum allowable radius of bends is five times the cable diameter. Though this bend limit is similar to that for armored cable (Section I), nonmetallic-sheathed cable can be bent in a smaller arc because the cable diameters are smaller for the same wire-gauge combinations.

BOX CONNECTION

Cable runs must be continuous from outlet to outlet because wire splices are only permitted inside a box. Type NM cable is prepared for box connection in the same manner as that outlined for armored cable. When removing the protective sheathing from the conductors for connection, use an electrician's knife instead of a hacksaw. When removing the covering, cut a slit in the sheathing parallel to the wires without touching the individual wire insulation. A cut approximately 8 inches long for cable entry to ordinary boxes is satisfactory but can be increased to suit entry to panels. Then, use the knife to remove the slitted sheathing.

You should also remove the moisture-preventive paper from the wires. *Figure 4-5, page 4-8,* illustrates the slitting of a cable end and shows a special tool called a *cable stripper* that can be used instead of a knife to remove the sheathing from Type NM cable, lead-covered cable, and portable cords. The stripper is inserted over the cable, squeezed together, and then pulled off the conductor. This action rips the outer sheathing quickly and efficiently. The use of a stripper instead of a knife for outer sheathing removal is recommended since it cannot damage the wire insulation.

ENTERING BOXES

When wiring with nonmetallic-sheathed cable, you may use either metal or nonmetallic boxes. It would be difficult to recommend one type over the other because both have advantages. Several aspects of wiring, such as grounding and connecting cable to boxes, vary, depending on the kind of box used.

Metal Boxes

Cable must be secured to a metal box. You may do this by using either a box with built-in cable clamps or a separate cable

connector. Either way, remember to leave 6 to 8 inches of cable extending into the box for connections.

As with most other terminal connectors, a grounding screw or clip is equipped to receive only one wire. When you install a switch, a self-grounding receptacle, or a light fixture in the last box of a circuit run, attach the grounding wire of Type NM cable directly to the box.

When you install a box that is not at the end of a circuit or a receptacle that is not self-grounding, you must make one or more grounding jumpers. For the grounding jumper, use wire that is the same size as the circuit wires. Twist all grounding wires and jumpers together, and crimp them with a compression ring or secure them with a wire nut.

Nonmetallic Boxes

Cable knockouts in nonmetallic boxes are held in place with thin webs of plastic. Break out a knockout wherever Type NM cable will enter a box. Ensure that the cable is supported within 8 inches of the box, the sheathing extends into the box at least 1/4 inch, and the cable is secured to the box.

When you are fishing cable behind walls, above ceilings, or under floors, you are not required to support cable, but you must clamp the cable to the box. Nonmetallic boxes are available with built-in cable clamps.

Since nonmetallic boxes do not conduct electricity, they need not be grounded. When using nonmetallic boxes, treatment of the grounding wire is based on whether the box holds a receptacle, a switch, or a light fixture.

Receptacles. Attaching a receptacle to a nonmetallic box is a simple process. If the box is at the end of a circuit, attach the grounding wire to the grounding screw of the receptacle. If the box is in the middle of a circuit run, join the cable grounding wires with a grounding jumper from the receptacle.

Switches. Many switches are now equipped with grounding terminals, which are treated as those on grounded receptacles. When using such a switch and it is in a nonmetallic box in the middle of a run, join the cable grounding wires. If the switch is at the end of a circuit, hold the grounding wire between the switch bracket and the box with the mounting screw.

Light Fixtures. To install a light fixture, use an octagon-shaped fixture box with a metal grounding bar. If the fixture is at the end of a circuit, attach the cable grounding wire to the bar (*Figure 4-6*). If the fixture is in the middle of a circuit, make a grounding jumper to join the grounding bar to the cable grounding wires. The light fixture will automatically be grounded when attached to the grounded box. **NOTE: Some chain-hung fixtures have a separate grounding wire. Join it to the circuit grounding wire and a jumper.**

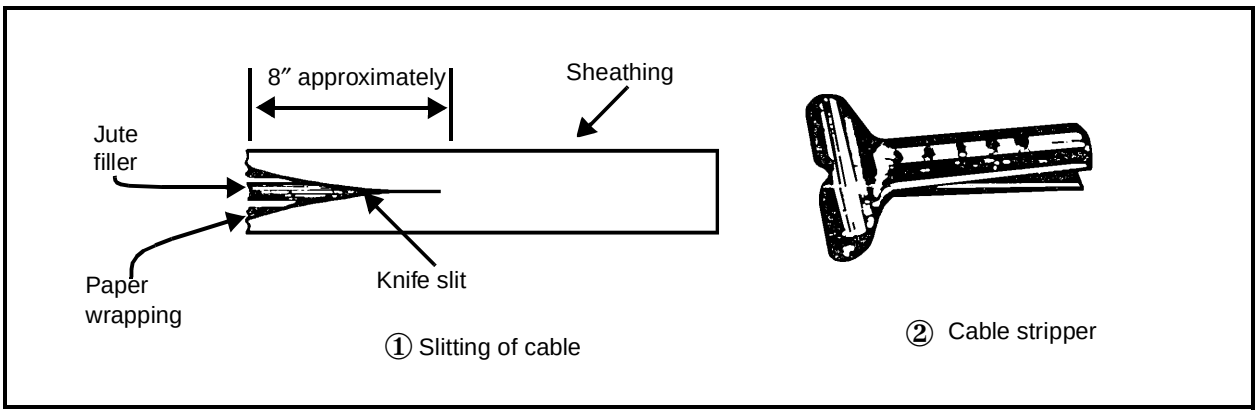


Figure 4-5. Removal of sheathing

ADDITIONS TO EXISTING WIRING CIRCUITING

The factors pertinent for additions to existing wiring systems are the same as those for Type NM cable wiring.

CABLE CONNECTIONS

Connection additions for nonmetallic-sheathed cable are the same as connection additions for armored cable outlined in Section I.

TYPE NM CABLE ADDITIONS

Exposed

The installation of exposed Type NM cable additions to existing wiring must conform to the same requirements outlined for original installations. If a wiring system other than nonmetallic-sheathed cable is to be extended with nonmetallic-sheathed cable, you must use a junction box to couple the systems. You may use existing boxes that have available spare conductor capacity.

Concealed

Additions to concealed nonmetallic-sheathed cable are similar in method and procedure to those for armored cable except that insulated receptacles, switches, and light fixtures may be installed without boxes on the wall surfaces. In these installations, the cable is fished through the wall and fed to the device at the point of entry.

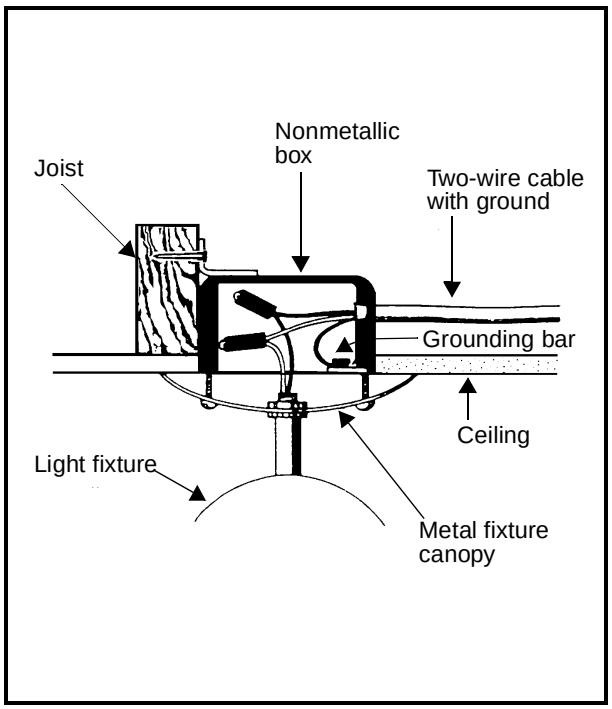


Figure 4-6. Ceiling-mounted light

Section III. Cable Fishing With Access

Fishing cable where you have access requires some fishing gear. *Fish tapes* are the tools to use for long cable runs. For shorter distances, you can use straightened coat hangers or lengths of No 12 wire with one end bent into a tight, blunt hook. Ensure that whatever you use is long enough to span the entire distance plus 2 feet. You need an open space to fish through. If you are going to attempt fishing more than a foot or so, you need a partner to accomplish the following steps *(Figure 4-7, page 4-10)*:

Step 1. Make a hole for the box in an open space between studs.

Step 2. Using a 3/4-inch spade bit, drill a hole up through the sole plate from the basement or down through the top plates from the attic. Drill until you hit open space; you may have to use an extension bit.

Step 3. To install a wire from the basement, run a fish tape through the box hole and down through the drilled hole. Attach the cable as shown in *Figure 4-7* and draw it into the box hole. To ensure that the passage is clear, have someone shine a flashlight in the box hole while you peer into the drilled

hole to see if the light beam is visible. If it is not, a fire block (or something else) is in the way. For drilling through this obstruction, you need several extension shafts for the drill bit. Drill through the block, then look for the light again. If you still cannot see the light beam, move to another location or cut away some of the wall covering and notch the block. Once the passage is clear, continue with steps 4 and 5.

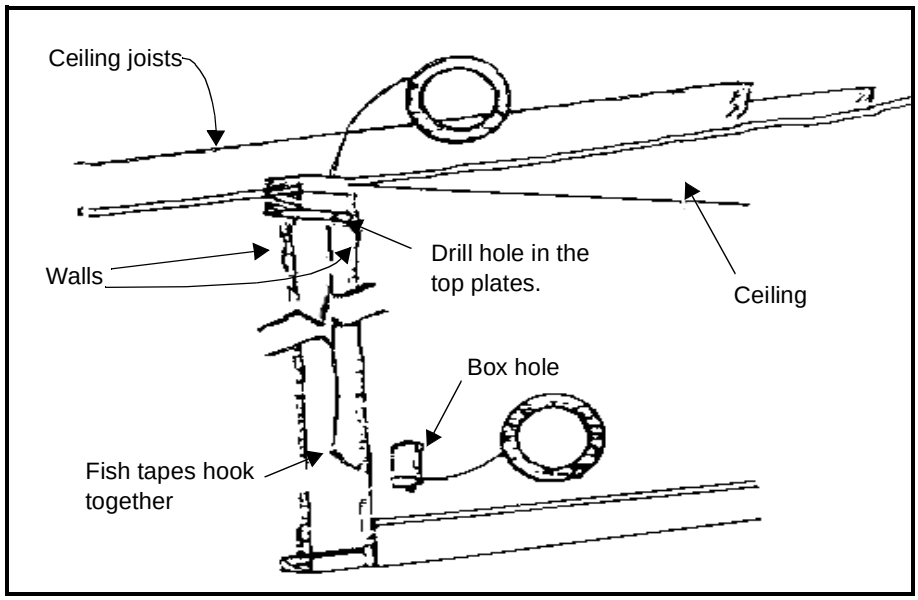


Figure 4-7. Method of fishing long run with access

Step 4. To install a wire from the attic, your partner runs a second fish tape or a length of small chain down through the hole in the top plates. Hook the two fish tapes together outside the box hole.

Step 5. You push the fish tape up through the wall while your partner pulls it until he has a secure grip on the tape coming up from the box hole. Attach the cable to the fish tape from the box hole and pull it slowly to work it through the wall to the box opening.

Section IV. Cable Routing Without Access

ROUTING BEHIND A BASEBOARD

Step 1. Cut the box hole or holes. Remove the baseboard between the box locations. Drill a hole through the wall below each box and cut a channel in the wall to connect the holes.

Step 2. Fish the cable down through one box hole, along the channel, and up into the other box hole.

ADDING A LIGHT AND A SWITCH

Step 1. Mark the fixture-box location between the two ceiling joists. Cut a hole for the box. At the ceiling edge between the same two joists, make a hole in the ceiling and the wall where they meet. Cut a hole for the switch box. Unless you want to run the cable through notched wall studs or behind the molding to another switch location, plan to locate the switch directly below the ceiling hole. Run the cable from the power source to the switch box.

Step 2. Run the fish tape down from the top wall hole to the switch-box hole. Connect enough cable for the switch loop and pull it up and out of the top hole.

Step 3. Run the fish tape from the fixture hole to the ceiling hole. Connect it to the switch loop cable and pull the cable out of the fixture hole.

Step 4. Notch the top plates to inset the cable and staple the cable in place. Connect the cables to the boxes, mount the boxes, and hook them up to the fixture and the switch.

ROUTING CABLE ALONG A WALL

Step 1. Cut box holes in the wall. Neatly cut away a straight, narrow strip of wall covering to expose all studs between the box holes. Both ends of this slot should be centered over studs.

Step 2. Use a 3/4-inch spade bit to drill through the center of each stud. Run the cable through the holes.

ROUTING CABLE AROUND A DOORWAY

Step 1. Remove the molding around the door frame and as much baseboard as necessary on either side of the door.

Step 2. Run the cable between the jamb and the frame, notching spacers wherever necessary. When routing cable behind molding, keep these points in mind:

- Ensure that you can get replacements because the molding may split.
- Use a 4-inch-wide or wider putty knife or electrician's chisel to pry molding from the wall.
- Use a 1/16-inch metal plate or run in thin-wall conduit to protect cable that is installed less than 1 1/2 inches from a finished surface.
- Do not nail through the cable when renailing the molding.

ROUTING CABLE THROUGH BACK-TO-BACK DEVICES

Step 1. Make a hole in the wall for the new box. De-energize the circuit you will be working on.

Step 2. Pull the device that is to be the power source out of its box. Remove the knockout from the back of the source box.

Step 3. Insert the cable with the connector through the new box hole into the source box. Connect the cable to the new box and mount the box.

Step 4. Wire in the new device. Wire into the source. Turn the circuit back on.

Section V. Finishing Up

MOUNTING BOXES

To mount a box, screw a cable connector to the box (or use a box with internal clamps that make fitting the box in the hole easier) and thread the cable through. Leave 6 to 8 inches of cable sticking out of the box for connections. For information on stripping and preparing the wires in the box, see Sections I and II. How you mount the box will depend on its type.

PLAIN BOX WITH BRACKETS

Check the box for proper fit in the hole. If necessary, adjust the ears so that the front edge of the box will be flush with the finished wall. Put the two brackets in the wall, one on either side of the box, and pull the bracket tabs toward you so that they are snug against the back side of the wall. Bend the tabs over the sides of the box and secure them with needle-nose pliers.

PLAIN BOX WITHOUT BRACKETS

Check the box for proper fit in the hole. If necessary, adjust the ears so that the front edge of the box will be flush with the finished wall. Mark the screw placements on the lath at the top and bottom of the hole. Remove the box and drill pilot holes for screws. Screw the box to the stud. On wooden walls, screw the ears to the wall surface. The faceplate will hide the ears and screws.

CUT-IN BOX

Mounting this box is a one-time proposition. Once inside the wall or ceiling, the side teeth flare away from the box, making it

difficult to remove. Tightening the screw at the back of the box simply pushes the teeth into the backside of the wall surface. Because you cannot remove the box, ensure that the cables are in place and the box fits the hole before you mount it. To test the fit, remove the metal spring ears from the box.

CEILING BOX ON HANGER BAR

If you do not have access from the attic, you must cut out the ceiling material between the two joists. Screw the hanger bar to the sides of the two joists.

CEILING BOX WITH OFFSET HANGER

This box works well where you do not have access from above. Screw the offset hanger bar to the bottom edges of two joists.

CEILING BOX WITH FLANGE

If you do not have access from above, you will have to cut out a rectangle from the ceiling material. Nail or screw the flange to a joist (*Figure 4-8*).

PANCAKE BOX

Simply screw this box to a joist or beam. Position the box so that it will hide the hole that was drilled for the cable. Do not make cable junctions in this kind of box.

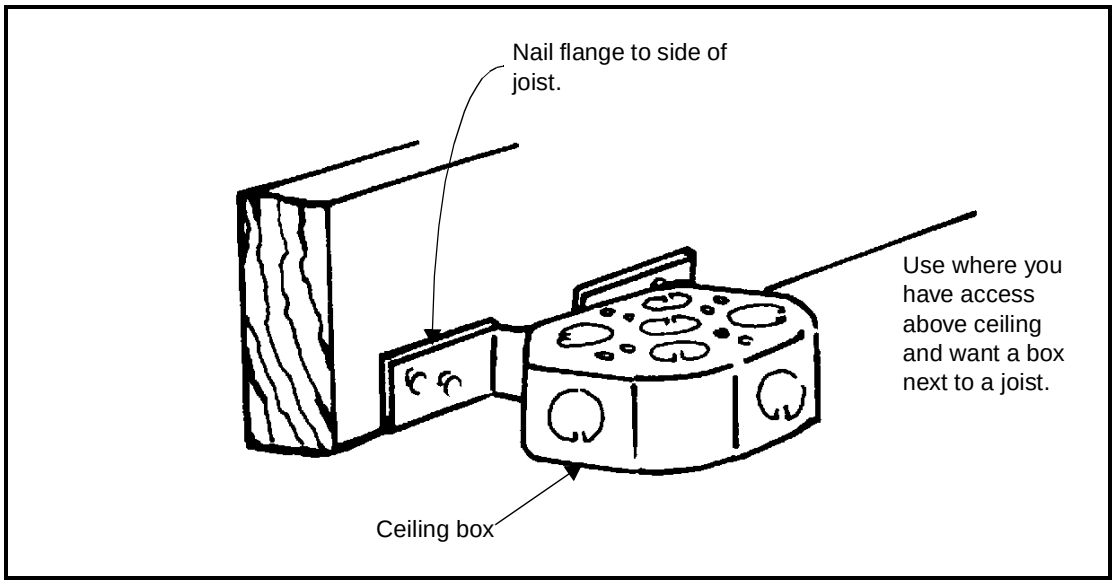


Figure 4-8. Ceiling box with flange

WIRING INTO THE POWER SOURCE

If your rewiring involves adding a new circuit to the service-entrance panel or a subpanel, see Chapter 3. *Figures 4-9 through 4-12, pages 4-13 and 4-14*, show how to wire in a new cable at a receptacle, switch, light, and junction box, respectively.

When adding a receptacle, use the checklist in *Table 4-1, page 4-15*, to review your work.

CAUTION

Before hooking up the new cable to the power source, shut off the main breaker or disconnect the circuit you are wiring into.

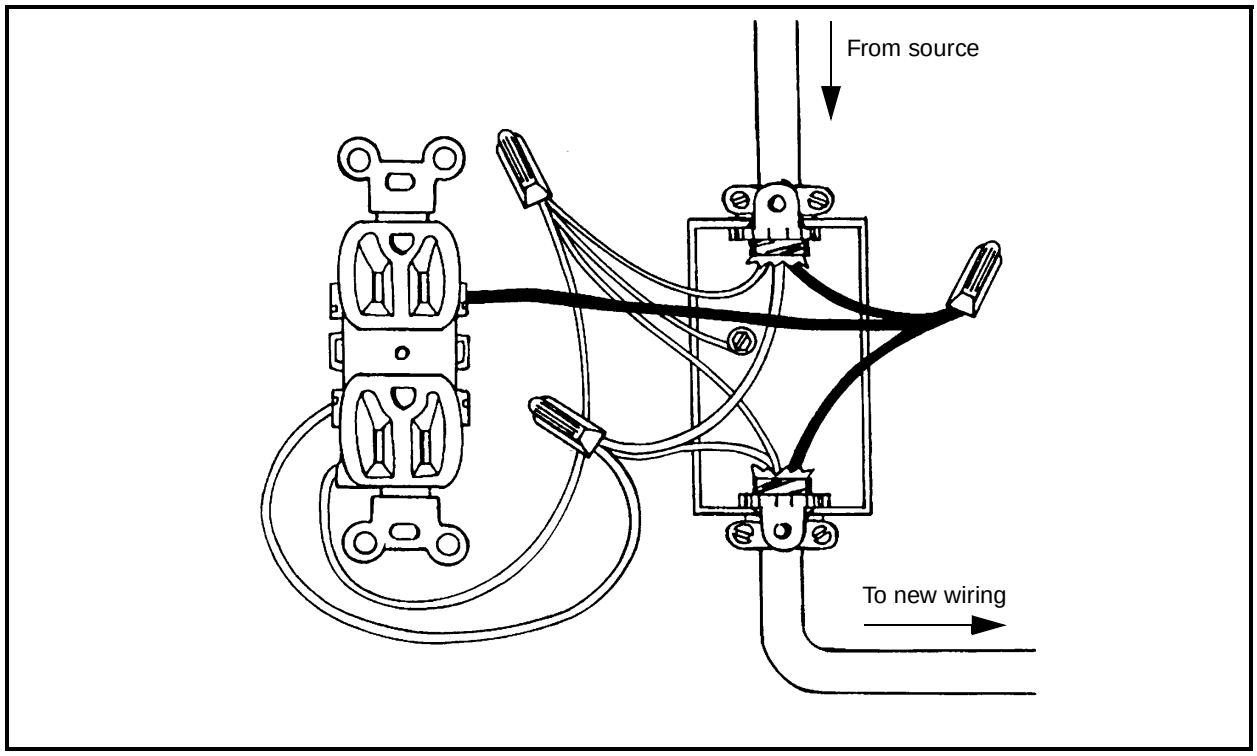


Figure 4-9. Method of wiring into a receptacle

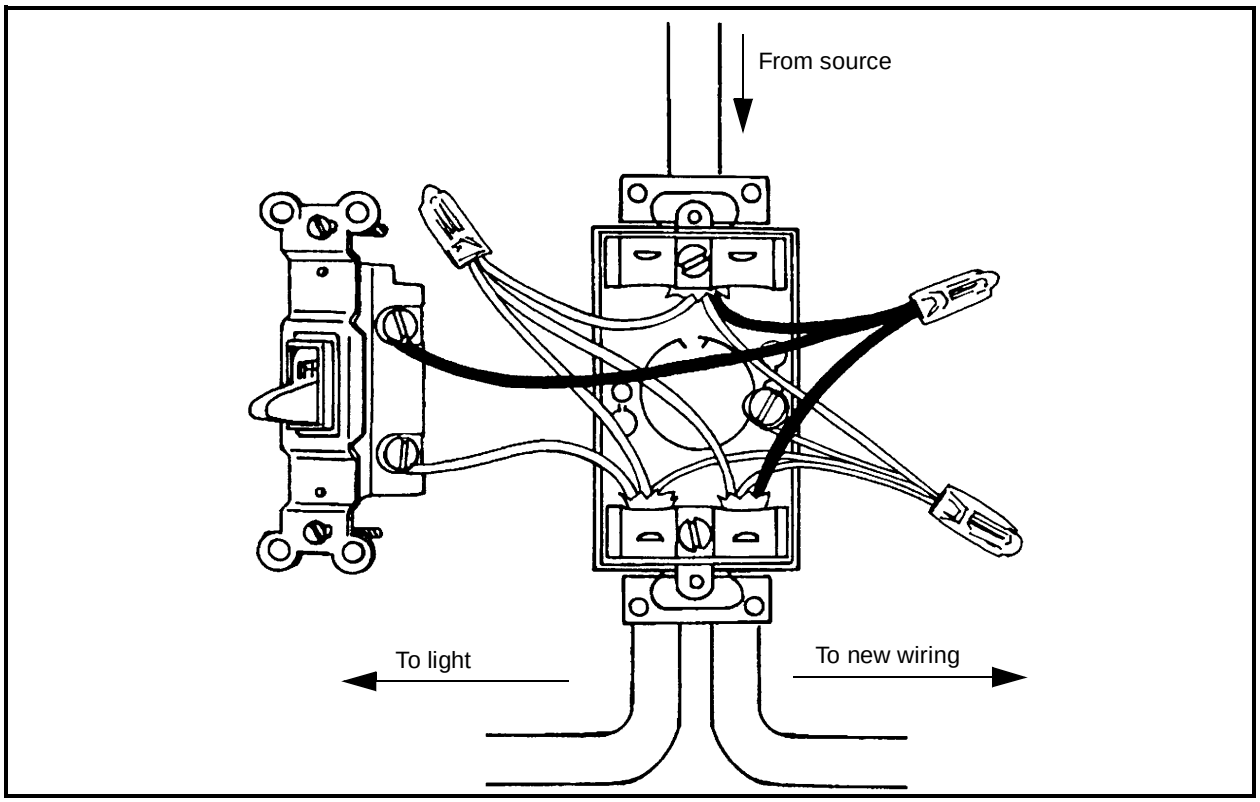


Figure 4-10. Method of wiring into a switch

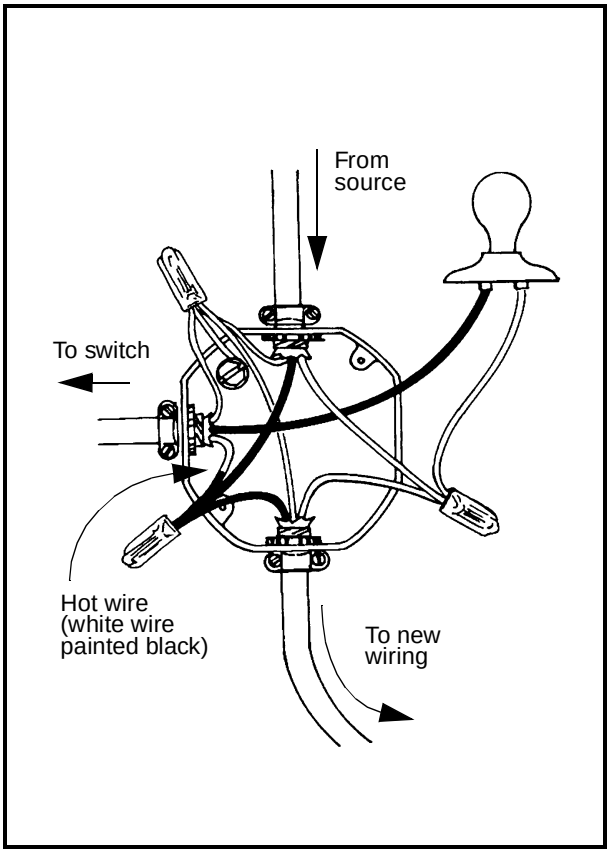


Figure 4-11. Method of wiring into a light

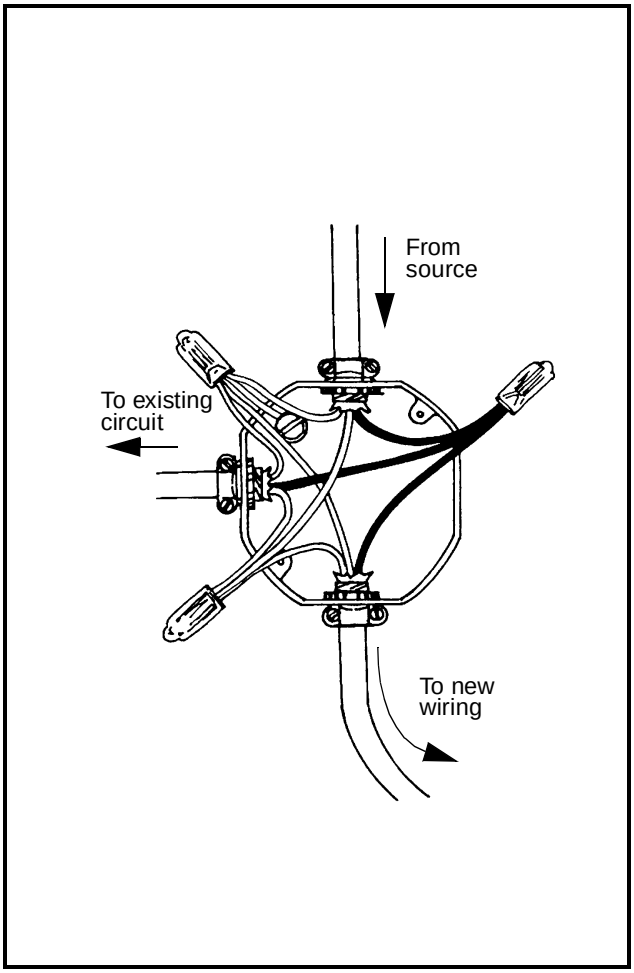


Figure 4-12. Method of wiring into a junction box

Table 4-1. Checklist for adding a receptacle

- ❑ De-energize the circuit you will be tapping into.
- ❑ Make a hole in the wall for the new box.
- ❑ Pull the device that is to be the power source out of its box.
- ❑ Remove the knockout in the source box that leads most directly to the new cable route.
- ❑ Remove the baseboard between box locations.
- ❑ Drill a hole through the wall below each box.
- ❑ Cut a channel in the wall between the two holes.
- ❑ Cut a length of cable, adding 2 feet extra for the box and device connections.
- ❑ Put the cable connector on one end of the cable and fish the cable through the hole in the wall and the knockout up into the source box.
- ❑ Connect the cable to the new box and mount the box.
- ❑ Wire in the new device and wire into the source.
- ❑ Put the faceplates on the boxes and turn the circuit back on.